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ALBERTA ENVIRONMENT
EARTH SCIENCES DIVISION - SOILS BRANCH

HYDROGEOLOGY OF THE
RILEY SITE

SUMMARY REPORT

A Site Evaluation for the
Proposed
SPECIAL WASTE MANAGEMENT FACILITY

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SECTION ONE

INTRODUCTION

A hydrogeologic investigation has been conducted on a quarter section of land legally described as NE 9-50-17-W4M, and referred to herein as the "Riley Site". This investigation forms one component of a site selection process initiated by Alberta Environment in a search for a location suited to development of a special waste management facility. Investigation of the Riley Site was phased, commencing in January and concluding in November, 1983. This report represents a summary of the final report, which contains a more detailed text, geologic and hydrogeologic maps and cross-sections at a scale of 1:2000, and appended lithologic and hydrogeologic details.

SECTION TWO

LOCATION AND CURRENT LAND USE

2.1 Location and Access

Section 9-50-17-W4M is the legal location of a 640 acre parcel of land situated approximately 70 km southeast of Edmonton (Figure 2.1). The section is bounded on the south by the Village of Rley, on the east by Secondary Highway 854, on the west by an oiled county road, and on the north by a gravelled county road. Section 9 is located outside of the Village of Rley within the County of Beaver, but consideration has been given to transferring, via annexation, this parcel into the legal jurisdiction of the Village. Only the northeast quarter of Sec. 9 is under consideration for development of a Special Waste Management Facility.

As indicated in Figure 2.2, Section 9 can be accessed by roadways along all boundaries.

2.2 Land Use

A land use map is presented as Figure 2.2. Most of the Section is under private ownership and utilized for cereal crop production and pasture. The pasture/crop areas indicated in Figure 2.2 are based on interpretation of 1982 aerial photography. Development of the Section includes:

- (a) a farmstead in the southwest quarter,
- (b) small land holdings along the southern boundary of the southeast quarter,
- (c) a sewage lagoon system on the southeast quarter,
- (d) an abandoned railway spur extending diagonally from southwest to northeast, and
- (e) a pipeline along the eastern boundary.

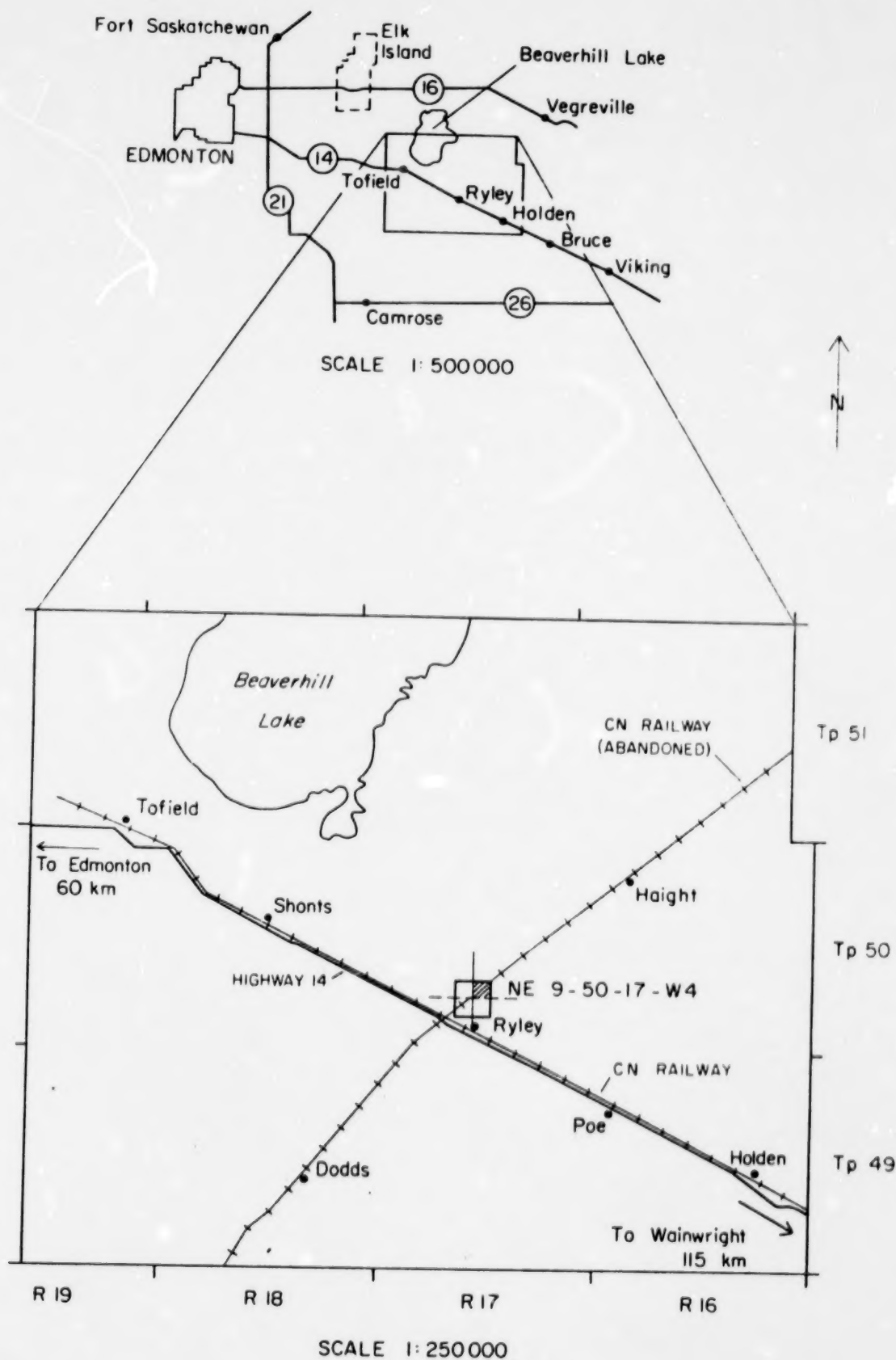


Figure 2.1 LOCATION AND ACCESS PLAN

A map of the study area showing land use, roads, and a railroad. The map is bounded by a double line representing a railroad (RR) running diagonally from the bottom-left to the top-right. The area is divided into several regions labeled with letters: C (Cultivated Land), P (Pasture), S (Shrubland), FS (Forest), SL (Shrubland), H (Habitat), and B (Barren). The map also shows a network of roads, including a 'Gravel Road' at the top and bottom, and 'Ciled Road' on the left and right sides. The scale is 1:10000.

Legend

RR - Railway

The farmstead is occupied by the landowner and includes outbuildings housing a dairy farm operation.

Small holdings include residential dwellings and land totalling less than 2 acres along the southern boundary of the southeast quarter.

A sewage lagoon system on the southeast quarter is owned by the Village of Rley. The system has been decommissioned in favor of a new facility located in Section 10 (adjacent). The decommissioned sewage lagoon system is retained by the Village, and is currently utilized for storm-water storage.

The railway bed complete with fenced right-of-way has been abandoned and tracks removed.

A small diameter gas line owned by Northwestern Utilities approximately parallels a fence line on the eastern boundary. The pipeline plan is only approximate owing to widening of secondary Highway 854 since the plan was prepared.

In addition to the above, several small waterbodies are delineated in Figure 2.2. These represent shallow sloughs characteristic of the Rley area in general, and result from poorly developed surface drainage in this area of the province.

The remainder of Section 9 is utilized for cereal crop production and pasture.

SECTION THREE

TOPOGRAPHY AND DRAINAGE

Topographic relief on the Ryley Site is limited, consisting of 3.8 metres between geodetic elevations 685.1 and 688.9 metres above sea level. The land surface is gently undulating with numerous shallow closed depressions located particularly on the southwest quadrant of the Site. No defined drainage courses exist, leaving surface drainage to accumulate locally within closed depressions. Topographic highs are distributed sporadically with no discernible land fall or rise in a particular direction.

SECTION FOUR

GEOLOGIC INVESTIGATION

4.1 Introduction

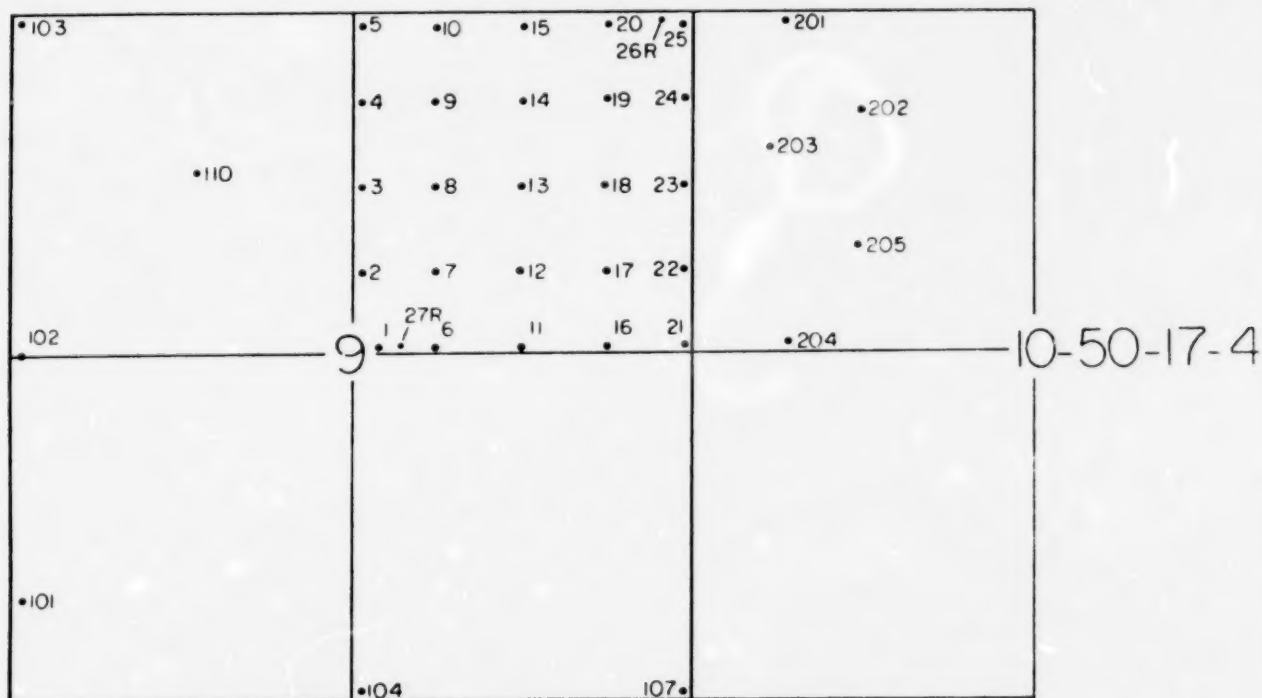
The subsurface geology of the Ryley Site was investigated by auger-drilling 25 boreholes on a 200-metre grid to a depth of 18 metres. Two rotary holes were each drilled to 90 metres. Additional boreholes (auger) were drilled on adjacent quarters as indicated in Figure 4.1. These were drilled at an early phase of the investigation in order to determine the most suitable quarter for a detailed investigation.

4.2 Surficial Geology

Surficial geologic deposits mantling the Ryley Site are of glacial origin, consisting primarily of clay-loam textured glacial till and sporadically-distributed occurrences of lacustrine clay and silty clay. The till and lacustrine deposits, collectively referred to as glacial drift, form a thin blanket ranging from 1.2 to 4.0 metres thick on the bedrock surface.

The thin drift cover, in conjunction with a gently undulating land surface comply with published information classifying surficial deposits mantling the Ryley area as "ground moraine".

Figure 4.1 TEST HOLE LOCATION PLAN
RILEY AREA



NOTES: All test holes drilled by dry auger
except 26R and 27R (Rotary)

4.3 Bedrock Geology

Cretaceous-age bedrock deposits beneath the Ryley Site consist of an unconsolidated, sedimentary sequence of sandstone, argillaceous (clayey) sandstone, sandy shale and shale. The sequence is interrupted by soft bentonite beds and thin, consolidated layers of sandstone and concretionary beds.

The sedimentary sequence within 90 metres (300 feet) of surface is separable into three informal members. The upper member consists of interbedded sandstone and shale with all textural gradations between the two types. The middle member is comprised exclusively of shale (middle shale member), and the lower member consists of interbedded sandstone and shale. Based on regional geologic data, it is considered that the boundary separating the middle and lower members represents the formational contact separating the Bearpaw and underlying Belly River.

4.3.1 Upper Member

The upper member ranges in thickness from 4.9 to 9.1 metres, with a mean thickness of 7.1 metres beneath the Ryley Site. The upper member is divisible into seven sub-units labelled A to G; the thickness of each sub-unit is variable between drill holes, and not all subunits are present at all drill locations. The subdivision units of the upper member are schematically illustrated in Figure 4.2.

SUB - UNIT

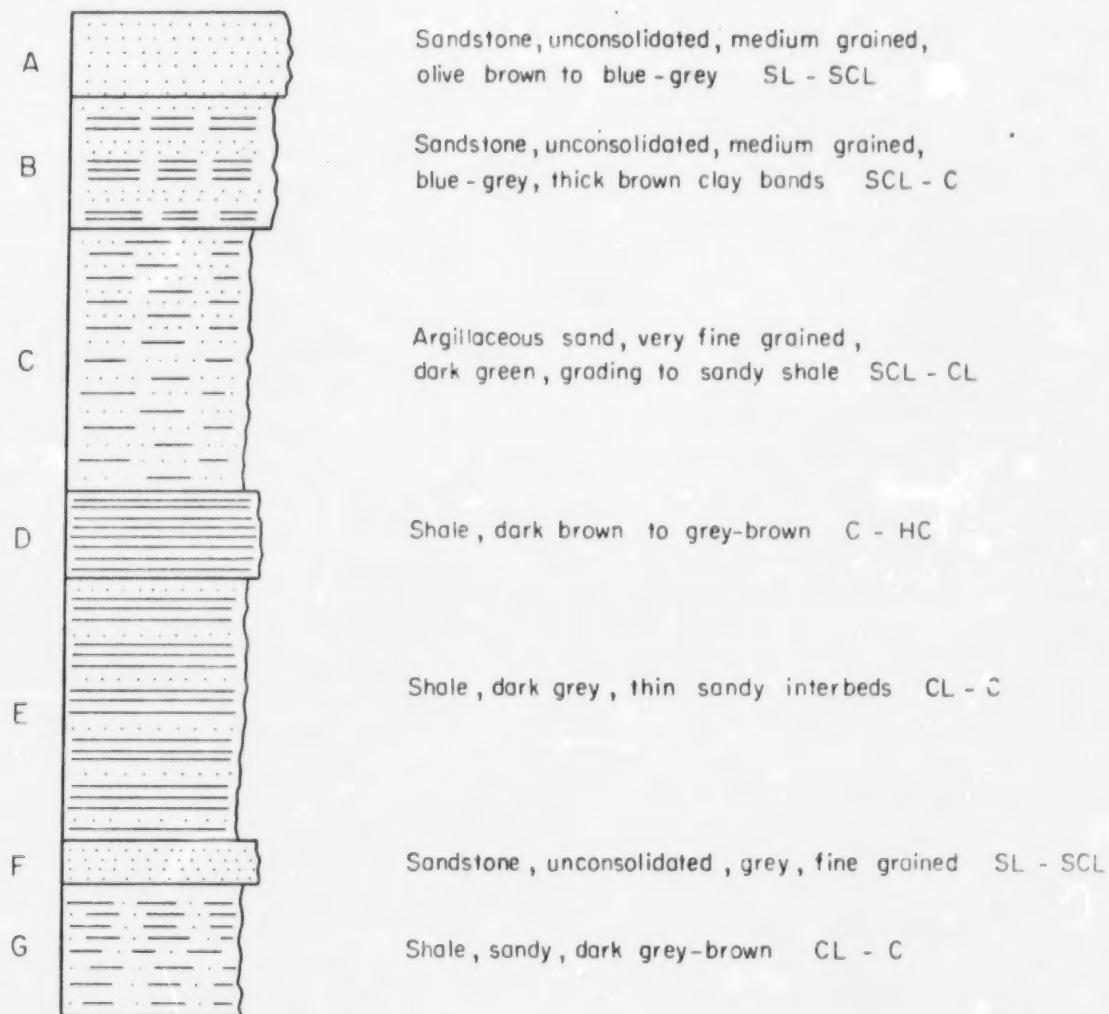


Figure 4.2 SUB-UNITS OF THE UPPER MEMBER

Most of the lithologic units represented in the upper member are not laterally continuous but grade one to the other indicative of rapid facies changes over short distances in the sedimentary environment. Two exceptions are noted; an unconsolidated sand representing the bed-rock subcrop is areally persistent beneath all of the Ryley Site (Unit A), and a shale unit at greater depth is areally persistent beneath a part of the site (Unit D).

The sands in the upper part of the upper member are commonly strongly glauconitic, with the glauconite content decreasing with depth. In addition, thin carbonaceous and lignitic streaks are encountered in both sand and shale units, and these beds are commonly associated with abundant fossil fragments. The fossiliferous, glauconitic, carbonaceous and lignitic horizons and beds within the upper member are not correlatable at the present map scale. However, the mineralogy and fossil content do indicate a marine origin and that these sediments are part of the Bearpaw Formation.

Very little free water was encountered in sediments of the upper member, and none of the units described in this member exhibit aquifer potential.

4.3.2 Middle Shale Member

The middle member consists of a uniformly fine-grained shale interrupted only by thin bentonite seams and concretionary beds. This member is in the order of 24 metres thick and the top lies in the range of seven to 11.6 metres below land surface. The base of the middle shale unit is arbitrarily placed at the contact with the first sandstone horizon encountered beneath this unit.

The middle shale member is variable in colour from dark brown to dark grey and readily distinguished from the upper member by the absence of glauconite; the shale exhibits a narrow textural range, varying from clay to heavy clay. Fossil fragments generally resembling nautiloids are sporadically distributed throughout the middle shale member and indicate that the sedimentary sequence to the contact with the lower member is of marine origin, and part of the Bearpaw Formation.

4.3.3 Lower Member

The lower member extends from depths in the order of 33 metres to the 90 metre depth base of exploration. Sediments within this unit are unconsolidated for the most part, and consist of grey and green sandstone, siltstone and shale. Both shale and sandstone sequences are occasionally carbonaceous or lignitic. The sedimentary sequence is interrupted locally by consolidated concretionary and soft bentonite horizons. Marine invertebrates or fossils of any type were not observed in cuttings from two boreholes which penetrated the lower member.

As indicated previously the contact between the middle shale and lower member is arbitrarily placed at the first sandstone bed encountered beneath the middle shale. Overlying sediments contain glauconitic sands (upper member) or fossil fragments (middle member) which indicate a marine origin. The lack of either fossils or glauconite in the lower member suggests that this unit is of non-marine origin. It is assumed, therefore, that the upper and middle shale members represent sediments of the Bearpaw Formation, and that the lower member is part of the Belly River Formation. The depth of contact between the middle shale and lower member (33 metres) is in good agreement with published information placing the Bearpaw-Belly River contact at approximately 30 metres below surface in the Ryley area.

4.4 Particle Size Distribution

Samples of geologic materials from selected depths were obtained for particle size analysis. Borehole 19 was sampled periodically from 0.6 to 16.8 metres below surface (14 samples) and borehole 26 was sampled from 23 to 81 metres below surface (15 samples). The samples obtained are representative of various stratigraphic units penetrated during exploratory drilling.

Results of particle size analyses are listed in Table 4.1. As indicated in the table, materials described as "sandstone" range texturally from sandy loam through sandy clay loam to clay loam. While the term sandstone connotes a coarse-grained material with a relatively high hydraulic conductivity, sandstones beneath the Ryley Site are unconsolidated and contain appreciable amounts of clay and silt.

The vertical variation in texture, and weight fraction of sand, silt and clay sized particles are illustrated graphically in Figures 4.3 and 4.4. The middle shale member is easily recognizable in the graphic displays, revealing a uniformly fine-grained texture with a low sand, moderate silt, and high clay content. The sand content increases with depth in the middle shale member, indicating a vertical gradation from shale downward to sandy shale.

Samples of upper member sands were also taken from boreholes 7 and 9 in order to obtain laboratory textures of the coarsest materials available within this member. In addition, 53 samples from the upper and middle shale members were taken during piezometer installation. These latter samples were taken from the zone in which the piezometer tips were completed in order to compare hydraulic conductivity values with the texture of zones being tested. The results of textural analysis on 90 samples collected from beneath the Ryley Site are summarized in Figure 4.5.

Table 4.1: Particle Size Analysis of Geologic Materials

Sample No.	Depth	Material	*Texture
R19-1	0.6 m	Till	CL
2	1.5	Shale	C
3	2.0	Shale	CL
4	3.0	Sandstone	SCL
5	4.5	Shale	C
6	6.0	Shale	C
7	6.6	Sandy Shale	SCL
8	7.5	Shale	C
9	9.6	Shale	C
10	10.7	Shale	HC
11	12.2	Shale	HC
12	13.7	Shale	HC
13	15.2	Shale	HC
14	16.8	Shale	HC
R26-1	23.0	Shale	HC
2	28.0	Shale	C
3	34.0	Argillaceous sandstone	C
4	36.0	Sandstone	C
5	38.0	Sandstone	SL
6	42.0	Shale	C
7	46.0	Shale	C
8	54.0	Argillaceous sandstone	CL
9	58.5	Shale	CL
10	60.0	Argillaceous sandstone	SiC
11	64.0	Sandstone	SCL
12	69.0	Shale	CL
13	71.0	Sandstone	SCL
14	78.0	Shale	C
15	81.0	Shale	C

Upper Member - Bearpaw

Middle Shale Member - Bearpaw

Lower Member - Belly River

* Legend

SL - Sandy Loam
 SCL - Sandy Clay Loam
 CL - Clay Loam
 SiC - Silty Clay
 C - Clay
 HC - Heavy Clay

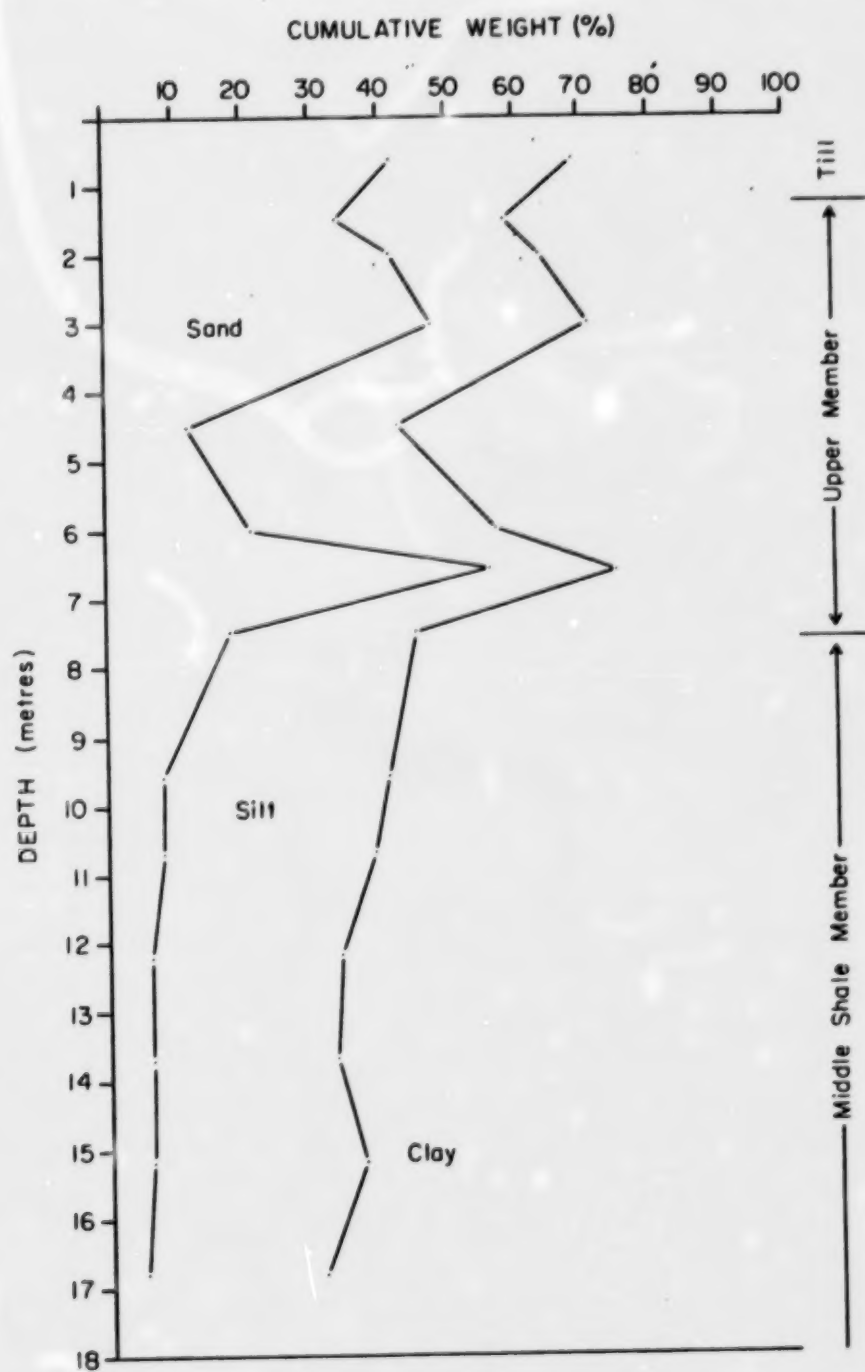


Figure 4.3 TEXTURAL VARIATION WITH DEPTH
(TEST HOLE 19)

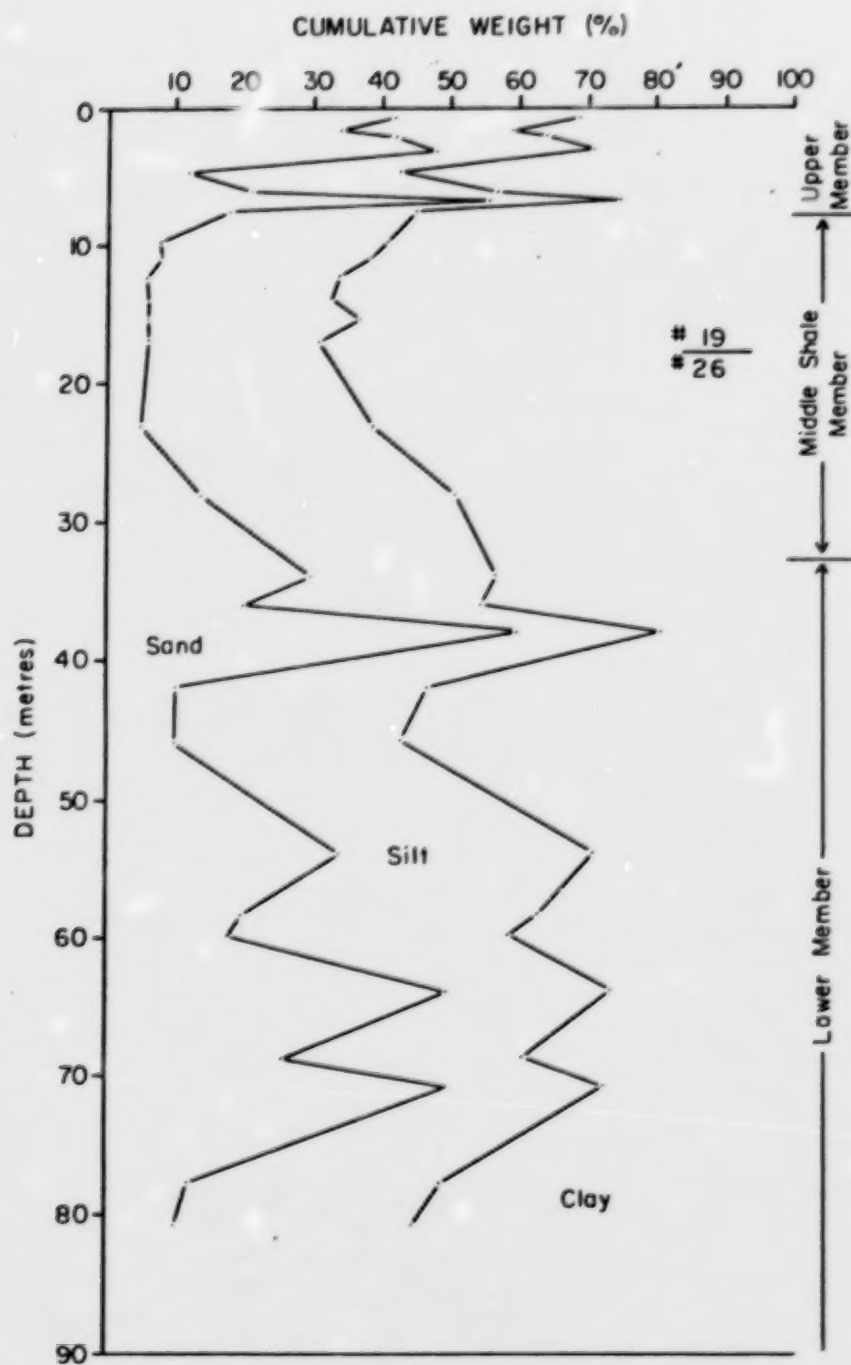
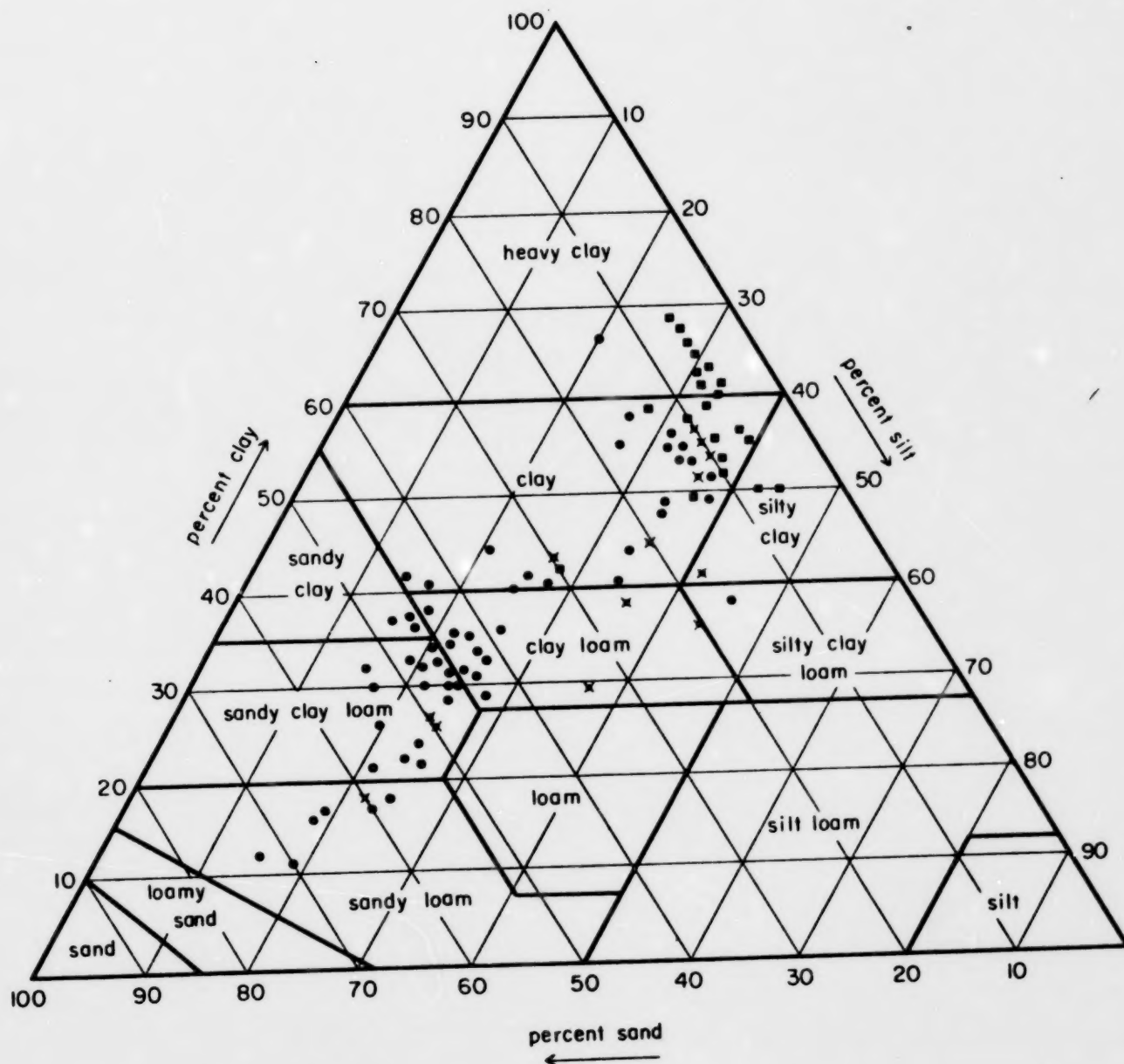


Figure 4.4 TEXTURAL VARIATION WITH DEPTH
(TEST HOLES 19 and 26)

Figure 4.5 PARTICLE SIZE DISTRIBUTION



- Upper Member
- Middle Shale Member
- × Lower Member

SECTION FIVE

GROUNDWATER

5.1 Introduction

The groundwater investigative phase includes determination of watertable depth, horizontal components of groundwater flow, and velocity or rate at which groundwater migrates within the near-surface sediments. Investigation of these parameters was restricted to within the upper 18 metres (60 ft.) of the stratigraphic sequence, which includes the upper member and the upper part of the middle shale member. A total of 77 piezometers were installed at 25 locations on the Ryley Site for this purpose (Figure 4.1).

The aquifer potential of sediments within 90 metres (300 ft.) of surface was investigated by drilling, E-logging and testing (air compressor) two uncased test holes. These were located in the northeast and southwest corners of the Ryley Site as indicated in Figure 4.1.

5.2 Watertable Depth and Configuration

Based on 25 control points, the watertable beneath the Ryley Site currently ranges in depth from less than one to approximately six metres below surface. This range is subject to adjustment as a number of piezometers have not attained stabilized levels in the poorly-permeable fine-textured sediments.

The watertable attains its highest elevation beneath sloughs in the southwest quadrant of the site. A contour map of the watertable surface indicates radial flow in all directions from beneath the southwest quadrant. Flow lines drawn perpendicular to the equipotential (contour) lines indicate the dominant direction of groundwater flow is eastward. As will be presented in later sections, however, the

geologic sequence to a depth of 30 metres consists primarily of impermeable sediments, and it is unlikely that groundwater attains any appreciable velocity along the flow paths indicated by declining hydraulic potentials.

5.3 Hydraulic Conductivity of Geologic Materials

Results of hydraulic conductivity determinations from single-well response tests are contained in Table 5.1. Of the 71 available results, six indicate conductivities in the order of 10^{-6} , 12 in the order of 10^{-7} , 33 in the order of 10^{-8} , and 19 in the order of 10^{-9} cm/s. A single K value of 1.2×10^{-4} cm/s (piezometer 24C) is anomalously high for shale in which the piezometer is completed. Moisture streaks were noted at this depth during construction, and it is considered that the piezometer is completed in fractured shale. No other evidence for fracturing is identified based on response test data available to date.

The response test data indicate that geologic materials beneath the Ryley Site should, for all practical purposes, be considered "impermeable". The exception is piezometer 24C where fractures are likely present at the 9.8 metre depth. There is no indication, however, that fracturing is a wide-spread phenomenon in the subsurface, based on the results of tests carried out to date.

TABLE 5.1: Hydraulic Conductivity of Geologic Materials

Piezometer No.	Depth (m) Below Surface	Geologic Medium	Hydraulic Conductivity (cm/s)
1N	18.82	SH	(2.2×10^{-8})
1C	10.59	SH	7.8×10^{-8}
1S	5.32	SS	1.1×10^{-6}
2N	18.42	SH	3.4×10^{-7}
2C	No Test - Low Static		
2S	7.39	SS	(2.4×10^{-8})
3N	18.54	SH	2.1×10^{-7}
3C	11.50	SH	(1.9×10^{-8})
3S	7.92	SH & SS	3.1×10^{-7}
4N	18.46	SH	(7.8×10^{-9})
4C	9.69	SH	(1.4×10^{-8})
4S	5.26	SS & SH	1.2×10^{-6}
5N	18.14	SH	(1.7×10^{-8})
5C	9.19	SH & SS	(9.1×10^{-9})
5S	6.27	SH	(1.3×10^{-8})
6E	18.59	SH	(9.1×10^{-9})
6C	12.17	SS & SH	2.6×10^{-7}
6W	7.46	SS & SH	(3.6×10^{-8})
7E	18.73	SH	1.7×10^{-7}
7C	8.90	SH & SS	(2.7×10^{-8})
7W	4.70	SS	2.0×10^{-6}
8E	18.65	SH	1.0×10^{-7}
8C	9.96	SH	6.3×10^{-8}
8W	5.27	SS & SH	5.7×10^{-7}
9E	18.46	SH	(7.8×10^{-9})
9C	9.80	SS & SH	(7.8×10^{-9})
9W	6.71	SS	(9.4×10^{-9})
10E	18.13	SH	5.7×10^{-7}
10C	9.44	SH	(9.9×10^{-9})
10W	6.63	SH	5.0×10^{-7}

TABLE 5.1: Hydraulic Conductivity of Geologic Materials - Continued

Piezometer No.	Depth (m) Below Surface	Geologic Medium	Hydraulic Conductivity (cm/s)
11E	19.10	SH	(1.9×10^{-9})
11C	11.13	SS & SH	(9.0×10^{-9})
11W	4.62	SS	7.5×10^{-6}
12E	18.55	SH	(1.8×10^{-8})
12C	9.16	SS & SH	(1.0×10^{-8})
12W	6.73	SH	5.5×10^{-7}
13E	18.23	SH	6.2×10^{-8}
13C	11.32	SH	1.4×10^{-6}
13W	8.06	SH & SS	(1.1×10^{-8})
13S	6.59	SH	(9.1×10^{-9})
14E	No Test - Low Static		
14C	11.16	SH	4.2×10^{-8}
14W	6.80	SH & SS	(1.2×10^{-8})
15E	18.23	SH	(7.8×10^{-9})
15C	9.64	SS & SH	(1.3×10^{-8})
15W	6.64	SS	(1.1×10^{-8})
16E	17.63	SH	(1.6×10^{-8})
16C	9.27	SS & SH	(3.3×10^{-8})
16W	5.16	SS	1.6×10^{-6}
17E	18.46	SH	(2.2×10^{-8})
17C	10.59	SH	3.0×10^{-7}
17W	8.25	SS & SH	5.8×10^{-8}
17S	5.25	SS	(1.8×10^{-8})
18E	18.56	SH	(1.3×10^{-9})
18C	8.26	SS & SH	(1.7×10^{-8})
18W	4.92	SS	2.5×10^{-7}
19E	17.72	SH	(1.1×10^{-8})
19C	9.84	SH	4.3×10^{-8}
19W	6.14	SS & SH	(1.4×10^{-8})

TABLE 5.1: Hydraulic Conductivity of Geologic Materials - Continued

Piezometer No.	Depth (m) Below Surface	Geologic Medium	Hydraulic Conductivity (cm/s)
20E	No Test - Low Static		
20C	No Test - Low Static		
20W	6.92	SH & SS	(9.9×10^{-9})
21E	18.34	SH	(3.9×10^{-9})
21C	No Test - Low Static		
21W	6.16	SS & SH	(9.3×10^{-9})
22N	18.47	SH	(1.6×10^{-8})
22C	7.49	SS	7.8×10^{-8}
22S	5.25	SS	(7.0×10^{-9})
23N	18.65	SH	(1.2×10^{-8})
23C	7.99	SH	(1.2×10^{-8})
23S	6.16	SS & SH	(1.2×10^{-8})
24N	18.26	SH	(8.7×10^{-9})
24C	9.84	SH(moist)	1.2×10^{-4}
24S	No Test - Low Static		
25N	18.11	SH	(6.8×10^{-9})
25C	9.98	SH	(9.0×10^{-9})
25S	6.72	SH	(1.1×10^{-8})

NOTES:

SH - Shale

SS - Sandstone

Bracketed K values are estimates based on initial recovery data from in-progress response tests.

5.4 Horizontal Groundwater Flow

Regardless of the relative impermeability of subsurface geologic materials, groundwater will tend to flow in response to the hydraulic gradients presented by an irregular watertable surface. The velocity at which groundwater flows is related to hydraulic conductivity (K), hydraulic gradient (dh/dl) and effective intergranular porosity (N) in accordance with the following:

$$V = \frac{K \frac{dh}{dl}}{N} \quad (\text{Equation 5.1})$$

where V represents the mean linear velocity through a porous medium. Since the watertable is depicted as a curvilinear plane, the hydraulic gradient will vary from point to point on the watertable surface. In addition, the hydraulic conductivity is variable in the subsurface as indicated by K values ranging over three orders of magnitude (Table 5.1). The variable nature of constant parameters shown in Equation 5.1 will, therefore, produce variations in velocity from point to point in the subsurface. In order to determine a possible range in the mean linear groundwater velocity, one can manipulate various combinations of conductivity and gradient to produce minimum and maximum groundwater flow velocities. The hydraulic gradient, as measured from equipotential lines along the projected path of groundwater flow varies between 2.3×10^{-3} and 3.8×10^{-2} . The hydraulic conductivity ranges between 7.0×10^{-9} and 7.5×10^{-6} cm/s (discounting the fracture horizon encountered beneath piezometer location 24). Assembling the conductivity and gradient values into various combinations, holding effective porosity constant at 20%, and solving Equation 5.1 for the four possible combinations results in a "velocity matrix" as follows:

K =		7.0 x 10 ⁻⁹	7.5 x 10 ⁻⁶
$\frac{dh}{dT}$ = 2.3 x 10 ⁻³ = 3.8 x 10 ⁻²	Minimum Velocity	8.6 x 10 ⁻⁸ cm/s	
	8 x 10 ⁻¹¹ cm/s		
		Maximum Velocity	1.4 x 10 ⁻⁶ cm/s
	1.3 x 10 ⁻⁹ cm/s		

From the matrix, the mean linear velocity of groundwater flow might be expected to vary in the range of 8 x 10⁻¹¹ to 1.4 x 10⁻⁶ cm/s, which, when converted to more recognizable terms, is in the very broad range of 1 cm/century to 45 cm/year.

It should be recalled, however, that the watertable (or perched watertable) surface is not of a constant shape, but changes seasonally with variations in infiltration and evapotranspiration. Hydraulic gradients observed on the watertable surface may vary beyond the extremes observed currently, which will also vary the mean groundwater velocity beyond its calculated range. Since a large number of shallow piezometers have not attained stabilized levels, the maximum hydraulic gradient observed results primarily from such instability, and will be reduced with time. It is considered, therefore, that the mean linear intergranular groundwater velocity beneath the Ryley Site will approach the minimum rather than the maximum end of the calculated range.

The velocity of groundwater flow is an important consideration in the selection of waste management sites, since the potential exists for transportation of water-soluble contaminants via the groundwater system. It should be appreciated, however, that neither dissolved nor suspended contaminants can be transported at velocities equivalent to that of groundwater. A number of retardation mechanisms within the hydrogeologic environment serve to reduce contaminant velocity to less than that of groundwater, namely chemical and physical dispersion, ion exchange between groundwater and the transporting geologic media, and direct filtration of contaminant molecules which cannot physically pass through available pore spaces. Maximum contaminant velocity will, therefore, be less than the maximum mean linear velocity calculated previously. It is considered that retardation mechanisms will be particularly effective in the case of the Ryley Site; the subsurface geologic materials are predominantly of a very fine grain size which will promote chemical and physical dispersion, and the high clay content will provide abundant opportunity for the transfer of mobilized contaminants to the surfaces of clay minerals.

5.5 Availability of Contaminants

The foregoing section assumes that contaminants will be available for transfer within the groundwater system, and discusses the possible fate of these as they migrate within the subsurface. It is our understanding, however, that the special waste treatment facility will incorporate the highest treatment technologies available during the course of operation; the technology proposed will eliminate or greatly reduce the availability of free-contaminants to enter and migrate within the shallow groundwater system. Processes to be employed will require landfill disposal of inert or insoluble residues only, including inert incinerator residues and chemically fixed inorganic liquid or sludge waste streams. Given the nature of treated materials requiring land

disposal, the volume of free contaminants available for transport via the groundwater system will be negligible. None-the-less, our selection procedures in the search for suitable sites in the Province require that potential contaminant velocity in the subsurface be negligible, and we are recommending that engineering measures to enhance the natural geologic setting be incorporated within the site design.

5.6 Vertical Groundwater Flow

At the present time, determination of whether the Ryley Site resides in a recharge or discharge area is not possible since a number of piezometers are recovering either since installation or since initiation of response tests. The existence of recharge or discharge conditions is not considered particularly important, however, as the textural and conductive properties of geologic materials in the subsurface would not allow significant downward groundwater flow even in the event that recharge conditions eventually proved dominant. The hydraulic conductivity values obtained to date indicate horizontal conductivities in the range of 10^{-9} to 10^{-6} cm/s; owing to stratification in the sedimentary sequence, conductivity values in the vertical direction are expected to be at least an order of magnitude less than the horizontal. Given these values, the dominant direction of groundwater flow is expected to be horizontal and significant downward movement of groundwater is not anticipated. The existence of probable perched watertable levels at various locations beneath the Ryley Site support a lack of groundwater circulation to deeper flow systems within the hydrogeologic environment.

5.7 Groundwater Resources

Published information indicates that negligible quantities of producible groundwater are available from the stratigraphic sequence lying within 100 metres of ground surface. At depths greater than 100 metres, the production capability of aquifers increases marginally to within the range of 5-25 L/min. In addition, groundwater quality deteriorates rapidly with depth owing to increasing salinity.

In order to test the production capability of potential aquifers within the shallow subsurface, two rotary test holes were drilled on the Ryley Site, both to 90 metres below surface. The test holes were located respectively in the northeast and southwest corners of the quarter section (Test Holes R26 and R27, Figure 4.1).

Based on the E-logs, there is no evidence of any significant aquifers in the subsurface in either of test holes R26 or R27. Although sandstones are present at depths greater than 30 metres, these apparently contain a clay matrix sufficient to preclude a significant resistivity contrast.

Potential production from groundwater-bearing zones in the subsurface was estimated by air-lifting the total production from the 90 metre deep test holes. Test hole R26 yielded four litres per minute during 30 minutes of air-lifting, and test hole R27 yielded 18 litres per minute. It is considered that the total yield from both test holes was from sandstone sequences within the lower member as defined in this report. As indicated in Section 4.3.3 the contact between lower member and middle shale member lies at approximately 30 metres below surface.

SECTION SIX

SUMMARY AND RECOMMENDATIONS

6.1 Summary

Geologic materials beneath the Ryley Site consist of a glacial drift mantle overlying an unconsolidated sequence of Cretaceous-age sedimentary deposits. The drift cover consists primarily of clay loam-textured glacial till ranging from 1.2 to 4.0 metres thick. The Cretaceous sedimentary sequence was investigated to a maximum depth of 90 metres, and is separable into three informal members based on lithology:

- a) The upper member ranges from 4.9 to 9.1 metres thick and consists of a laterally discontinuous or gradational sequence of unconsolidated sands, argillaceous sands, sandy shales and shales. Each of the lithologic units within the upper member may be glauconitic, bentonitic, fossiliferous or carbonaceous/lignitic. The glauconitic mineralogy and fossiliferous character suggests a marine origin, and this member is considered as part of the Bearpaw Formation which reportedly subcrops in the Ryley area.
- b) The middle shale member is in the order of 24 metres thick and consists exclusively of dark brown and dark grey unconsolidated shale. The fossiliferous nature of the middle shale, though sparse, suggests a marine origin, and this member is also considered as part of the Bearpaw Formation.
- c) The lower member consists of an interbedded sequence of sandstone and shale; conspicuously absent are a glauconitic mineralogy within the sands, and any trace of fossils within either sands or

shales. The boundary between the middle shale and the lower member may represent the contact between the Bearpaw and underlying Belly River formations. The depth of this boundary (33 metres) is consistent with published data regarding the depth of the Bearpaw-Belly River formational contact.

The watertable lies at a depth ranging from less than 1 to approximately 6 metres below the Ryley Site. Based on the watertable configuration, groundwater flow within the shallow system of sediments is directed primarily eastward.

The hydraulic conductivity of geologic media within 18 metres of surface ranges from 1.3×10^{-9} to 7.4×10^{-6} cm/s, based on 71 test results presently available. A single value of 1.2×10^{-4} cm/s indicates the presence of fractured shales at one location. Based on the values of conductivity, and discounting the possibility of fracture flow, groundwater velocities within the shallow system of sediments beneath the Ryley Site lie within a calculated range of 8×10^{-11} to 1.4×10^{-6} cm/s (1 cm/century to 45 cm/year).

No aquifers or potential aquifers were encountered in either the upper or middle shale members, indicating an aquifer-barren lithologic sequence totalling 33 vertical meters beneath the Ryley Site. Sandstones in the lower member (Belly River Formation?) sediments are thick enough to be considered aquifers. Compressor tests indicate limited yields from the total thickness of these sandstones (four and 18 litres/min respectively from two 90 metre deep open boreholes). The results from the second borehole are higher than predicted for this interval from published data, while the results from the first borehole are in good agreement.

6.2 Recommendations

Hydrogeologic data collected during the present investigation confirm the setting of the Ryley area as presented in published maps and reports. The Ryley Site is considered to be hydrogeologically suitable for development of a special waste management facility with the following recommendations:

- 1) Surface drainage both on and off site should be improved to promote surface water runoff rather than collection and infiltration on site.
- 2) All landfill and land-based treatment components of the facility should be founded on specially prepared impermeable bases. The design of these components is an engineering responsibility, but should include over-excavation and recompaction to ensure that:
 - a) any potential fracture systems which may intersect these components are disrupted and sealed, and
 - b) only suitably-textured geologic materials are utilized at the bases and sides of landfill and land-based treatment components.
- 3) All waste materials which require final disposal by landfill should consist only of residues resulting from the various treatment processes proposed. These may include incinerator residues, sludges, liquids, or solids, but all wastes should be in a non-reactive form, immobilized by chemical fixation or otherwise permanently encapsulized.
- 4) A permanent system for monitoring groundwater levels and quality within the shallow groundwater system should be established concurrently with plant construction. Consideration should be given to permanent monitoring facilities located immediately beneath landfill and land-based treatment components of the facility.

- 5) All runoff from docking and treatment areas should be controlled and channelled to a central collection point. The quality of this water should be monitored, and treatment imposed where required.

Given the hydrogeologic setting of the Ryley Site, and implementation of recommendations contained herein, we consider that the proposed special waste management facility will be an environmentally sound operation in terms of potential for groundwater contamination. At the present time, the eastern and northern portions of the Ryley Site are the most suitable areas for development, as the watertable is lowest in these areas. Improvement of surface drainage, and elimination of sloughs which presently serve as infiltration basins to the shallow groundwater system will likely lower watertable levels beneath the southwest quadrant of the Ryley Site.

POOR

QUALITY

ORIGINAL

